I/S: A JOURNAL OF LAW AND POLICY FOR THE INFORMATION SOCIETY

From Big to Little Data for Natural Disaster Recovery:

How Online and On-the-ground Activities are Connected?

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Abstract: Following a major natural disaster, many turn to social media to communicate about their situation and try to seek help in disaster recovery. With millions of social media posts, it can be difficult for disaster management organizations to tap into these immense social networks to find the data needed and to connect individuals to networks that can provide assistance. This study takes big data analytic methods and applies them to a specific context, examining how active and influential members of Facebook groups aided in disaster recovery following Hurricane Sandy. It uses network analysis methods for finding influential members and a web-survey for learning about their background and volunteer activity inside and outside of their Facebook groups. The findings show that the majority of the active online members are also actively involved in on-the-ground recovery activities. They also have the capacity and willingness to work as volunteers. These members have

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important roles in the integration of online and on-the-ground disaster recovery efforts. Local governments and disaster management organizations should be prepared to incorporate social media data in their formal disaster recovery processes. This incorporation requires the integration of big data analysis methods with social science theories and methods.

I. INTRODUCTION

Scholars have widely discussed the importance of bottom-up processes in disaster recovery (See Burby, Deyle, Godschalk, and Olshansky 2000, 100 , 101; Chandrasekhar, 2012, 627; Knaap, Matier, and Olshansky 1998, 339, 340). These processes focus on the participation of local communities and stakeholders in helping local governments with recovery processes or initiating or facilitating grassroots and self-organized activities.

Although citizens are still active in traditional local groups and organizations (e.g., neighborhood groups, recovery committees, etc.) regarding disaster recovery activities, they are also increasingly participating in social networking sites and online forums. Examples of these forums include Facebook groups that were created after Hurricane Sandy for disaster response and recovery purposes. Several studies have examined the usability of social media in disaster management through exploring its utility in mediating social interaction and information sharing at or after the disaster time. A few studies have also explored the role of organizations in employing social media for disaster management. Still, our understandings of the background of online volunteers in social media groups and the relationship between their online and on-the-ground volunteer activities in disaster recovery are limited. Disaster management organizations and local governments fall short in understanding the dynamics of online social networks. This is partially due to their organizational insufficiency in handling big data generated through online social networks (Brynjolfsson 2012; Sagiroglu and Sinanc 2013; Townsend 2013). The network data can explain the interaction of the members in these groups. This data is not only valuable for local governments and disaster recovery groups to learn about citizens' interests and ideas, but also to explore the dynamics of these groups and identify potential stakeholders and volunteers as human resources in recovery processes (Paton and Flin 1999). Interpretation of this data requires understanding the social context of the disaster recovery process, including the involved stakeholders, through the

integration of social science methods with common big data analysis methods.

Focusing on 52 Facebook groups that were created after Hurricane Sandy, this study examines the background of the active members in these groups and explores if and how they could facilitate disaster recovery processes as volunteers or liaisons. It employs network analysis methods to identify the most influential and active group members, and a web-based survey to explore their backgrounds, intentions for online participation, and willingness to help as volunteers or liaisons. Instead of considering the overall potential network effects of Facebook in disaster recovery processes due to its large number of members (Chadwick 2008), this study explores Facebook's effect due to the role of its most influential participants. This study is not interested in looking at how interactions among different actors frame policies and strategies; instead, it focuses on using social network concepts as a general framework and method for identifying influential nodes (members) in networks. It uses the social network concept as a framework and employs specific network metrics as methods for identification.

While the role of social media as a medium for information dissemination and social interaction has been widely discussed, very few scholars have touched on exploring social media as a vehicle for learning about the dynamics of the social structures (See Hughes et al. 2014) generated through social media in disaster management. More precisely, few studies have explored who is behind online activities, and how these activities correspond and connect to on-the-ground disaster management efforts. While the current study seeks to answer these questions, its implications provide a framework that should prove useful in helping organizations to consider both whether and how to incorporate social media and big network data in formal disaster recovery processes.

II. STAKEHOLDER INVOLVEMENT IN DISASTER RECOVERY

With the increase in natural hazards as a result of climate change (Birkmann and Teichman 2010), local governments and institutions should be conscious of the availability of new sources for learning about the capacity of local communities, identifying potential stakeholders, or recruiting local volunteers. Several studies have emphasized the importance of stakeholders' and local communities' participation in disaster management and recovery processes (See Burby et al. 2000, 99; Chandrasekhar 2012; Knaap, Matier, and Olshansky 1998). Local governments and institutions adopt

community-based disaster management for reducing vulnerability to natural hazards and increasing response to emergency situations. It helps them with discovering problems, understanding contextual situations, increasing public awareness (L.-C. Chen, Liu, and Chan 2006), and even enhancing the legitimacy of their programs or policies (Peacock, Brody, and Highfield 2005, 121).

In addition, the capacity of local communities—including social, economic, and physical factors (Bolin and Stanford 1998; Buckland and Rahman 1999; Afzalan and Muller 2014)—plays an important role in their vulnerability to natural disasters. Human and social capital, encompassing income level, social networks, and ethnicity, affect communities' preparedness to respond to natural disasters (Buckland and Rahman 1999). Volunteer groups and local stakeholders provide valuable local knowledge regarding contextual considerations for local governments and disaster management organizations (Corburn 2009), while playing important roles as facilitators between government and citizens (Smith and Wenger 2004, 241).

Disaster management and recovery systems should support flexible communication processes (Chen, Liu, and Chan 2006) to adapt with changing environments (Berke 2006, 194), while protecting against sensitive data leakage. Volunteers and professional liaisons have important roles in these processes by providing a single point of contact and ensuring efficient coordination and communication of the activity of various organizations or sectors (Brucker and Hutter 2010). Liaisons can help with reducing stress in disaster response management through planning, communication, management, training, team development, and co-ordination (Paton and Flin, 1999). Identifying active community members provides a valuable basis for finding potential liaisons or volunteers for recovery purposes; stakeholder analysis can help with this process (Bryson 2007) by exploring the dynamics of citizen groups.

Due to the popularity of using social media among various groups of citizens during and after disasters, it is important to explore how the most active participants in these networks facilitate recovery processes inside and outside of their online communities. In addition, it is important that local governments examine ways in which they can identify and recruit active online members as potential volunteers or liaisons.

III. SOCIAL MEDIA, BIG DATA, AND NATURAL DISASTER MANAGEMENT

In 2010, social media was ranked as the fourth most popular source for retrieving emergency information (Lindsay 2010, 287). Be

that as it may, social media is more than just a medium for information dissemination. Local governments and non-governmental organizations can use social media in sharing or seeking information (Hughes et al. 2014; Hughes and Palen 2009; Palen and Liu 2007; Palen and Vieweg, 2008; Starbird and Palen 2010; Zook, Graham, Shelton, and Gorman 2010; Afzalan and Muller 2014), building relationships (Starbird and Palen 2010; Briones et al. 2011; White et al. 2009), educating citizens (White et al. 2009), mobilizing grassroots activities (Palen, Hiltz, and Liu 2007; Palen and Vieweg 2008), or raising situational awareness (Lindsay 2010). Local governments and non-governmental organizations can also use big data generated through online sources—including social media—to learn about the dynamics of cities' and communities' behavior (boyd and Crawford 2012; Brynjolfsson and McAfee 2012; Kitchin 2013; Sagiroglu and Sinanc 2013; Townsend 2013). While several scholars have explored the organizational considerations involved in incorporating big data in decision making and management in general (Brabham et al. 2014; Kitchin 2013; Sagiroglu and Sinanc 2013; Townsend 2013; Wigan and Clarke 2013; Afzalan and Muller 2014), not many scholars have explored this phenomenon in disaster management processes (See Hughes and Palen 2012; Hughes et al. 2014).

In response to a disaster, volunteers commonly use social media to connect to volunteer opportunities. Before the emergence and popularity of social media, citizens relied mainly on the news media; local governments; and, specifically, emergency officials for learning about disaster recovery news and events. Social media is now, however, facilitating information access and interaction among citizens for disaster recovery. Citizens have easy access to publicly available information and can search for support through online networks (Hughes and Palen 2012, 1). Some also volunteer during disaster times through distributing information, offering help, or self-organizing disaster response activities (Starbird 2011). These volunteer activities are more easily seen in social media, as altruistic values are more visible in this environment (Palen, Vieweg, Sutton, and Liu, 2007). Understanding the role of these online volunteers is valuable for local governments and disaster recovery organizations. Considering that group members in place-based online networks (e.g., online neighborhood forums) create face-to-face and on-the-ground interactions with other network members (boyd & Ellison 2007; Evans-Cowley 2010; Foth 2006; Tayebi 2013), disaster management organizations should understand who is behind online volunteer activities and if and how these activities are connected to on-the-ground recovery efforts. This understanding can help organizations

incorporate citizen-led and volunteer efforts into their disaster recovery process. Yet, the question is posed: Where do disaster management organizations stand in exploring these types of questions, and, more generally, in using big data analytic methods to connect to the public through social media in disaster management processes?

Recent studies show that, although local and non-profit organizations have started using social media for several purposes and in different stages of disaster management, these organizations still fall short in exploiting the potential of social media (Briones et al., 2011, 38). Several organizations, such as the Federal Emergency Management Agency, use social media mainly in a passive form for distributing information and receiving feedback from users. They rarely use it creatively and actively for other activities, such as monitoring citizens' online activities or using posted images for evaluating damage estimates (Lindsay, 2010, 287). Data generated through these systems is big and complex; these organizations are not familiar with the process of analyzing and understanding such big data.

Resources, mainly staff, time, and cost, are the main barriers to exploiting the full potential of social media and using the big data generated. Organizations need skilled staff for managing how to use data and the online forum (Brynjolfsson, 2012). In addition, persuading the relevant organizations' board members to use social media is not easy (Briones et al., 2011). Another challenge is learning about the identity and background information of the online participants, especially the active and influential ones, in online social networks (See Palen et al., 2010a). People are as concerned about sharing their identity in the online environment (Stutzman, 2005) or making their full profile information visible (Harrison & Thomas, 2009), as they are worried about organizational and social threats (Krasnova et al., 2009, 39). Yet good quality information is important in local disaster management and recovery processes (Palen, Vieweg, and Anderson, 2010, 10). Disaster recovery organizations should be equipped to evaluate the accuracy of the identity of online participants and those participants' backgrounds and skills. The institutional considerations of using technology for participatory governance requires modifying organizations' culture for the effective use of big data and web-based technologies in their management systems (Brynjolfsson, 2012).

With the increase in the participation of citizens in social media groups, institutions involved in disaster management should consider actively participating in these new social systems and making the

required organizational changes (Hughes and Palen 2012; Briones et al., 2011). For example, Hughes and Palen (2012) argue that social media expands the role of Public Information Officers (PIOs) and their interactions with citizens. They state that PIOs should keep up with fast-growing technologies used by citizens and stakeholders to be able to find valid communication channels for connecting with citizens (Hughes and Palen, 2012, 2). They argue that, in social media, PIOs should mainly work as translators who translate information in a way that makes it more comprehensible for the public. PIOs should be very well trained to distribute information and communicate effectively and accurately with citizens (15).

In sum, social media—including data generated through these platforms—introduce new opportunities and challenges in how communities and organizations communicate (Kietzmann et al., 2011, 250). Organizations should examine ways in which social media, as data generators in addition to social structures (Hughes et al., 2014), can be incorporated into formal disaster recovery processes. Analyzing big data generated through social media can help with understanding the identity and activity of people in these networks and examining the possibility of recruiting them as volunteers or liaisons in recovery processes.

III. BIG DATA ANALYSIS FOR IDENTIFYING POTENTIAL STAKEHOLDERS IN SOCIAL NETWORKS

There are a number of methods used for analyzing peoples' interactions and communications in social networks, including content analysis (See Starbird et al., 2010; Palen, Vieweg, and Anderson, 2010), sentiment analysis (See Evans-Cowley and Griffin, 2012; (Starbird et al., 2010) Dong, Halem, & Zhou, 2013) and Social Network Analysis (SNA). A social network consists of people, agents, or various types of social entities that are connected through social relationships (Garton, Haythornthwaite, and Wellman, 1997, 76). Content and sentiment analysis methods principally explore peoples' interests or ideas through quantitative or qualitative analysis of their posts or comments. This study focuses on SNA, as a big data analysis method, because it finds the most active members based on their interactions, relationships, and ranks in their social network. It considers social interaction and communications' dynamics, not data that are focused on the records of atomized behavior like credit card history. These "network data" are unique not only because of their big size, but also due to the level of detail they provide about networks' behavior (See González-Bailón, 2013).

SNA is a method for identifying stakeholders; exploring relationships among actors, communities, or organizations; and examining how stakeholders' expressions can influence organizations' work (See Prell et al., 2008; Hatala, 2006). SNA techniques are primarily derived from Graph Theory which explores how network agents are connected together and how network structures are organized (Linehan, Gross, and Finn, 1995; Chen, Chiang, and Storey, 2012). SNA is used in a wide number of fields, including information and computer science, economics, management, sociology, architecture, emergency management, and environmental planning (See Foulds, 1992; Linehan, Gross, and Finn, 1995; Minor and Urban, 2008; Wilson, 1976; Yamada, 1996; Zetterberg, Mörtberg, and Balfors, 2010). Governmental organizations and non-profits are increasingly interested in SNA as a stakeholder analysis method for strategizing their future actions, deciding how to react to stakeholders' behavior, and designing alternative approaches to achieving their goals. (Bryson, 2007, 43). Can SNA respond to this desire though?

Network structures in social media groups can be very complex. The activity of network members can affect network structure. Some people are passive members and create a fairly restricted network; on the other hand, others may be very active and connected to several other members, generating and regenerating networks of friends (Harrison and Thomas, 2009, 114). Network analysis helps with exploring the big data generated from complex networks. Several studies have employed network analysis for identifying influential members. Several propose models or algorithms for the identification of nodes that have maximum influence in spreading information through a social network (See Chen, Wang, and Yang, 2009; Kempe, Kleinberg, and Tardos, 2003). Studies have used different indexes and methods for analyzing the influence of nodes in networks. The following are the two main indexes used for this purpose.

A. *H-index*

This index is basically introduced to rank researchers based on their citations (Hirsch, 2005). This ranking index can be used for other studies, such as measuring career advancement of developers (Capiluppi, Serebrenik, & Youssef, 2012). In the context of Facebook groups, we consider a person to have an H-index of N, if N number of her posts received at least N likes and/or comments in total. Google Scholar, Scopus, Web of Knowledge, and many other scholarly search engines have widely used this indexing.

B. *i10-index*

Similar to H-index, this indexing is also used for ranking academics based on their publication and citations. This indexing method was introduced by Google in 2011 as a part of their work on Google Scholar (López-Cózar, Robinson-García, and Torres-Salinas, 2012). Using the definition given by Google, a person has an i10-index of N if she has at most N publications, each cited at least 10 times in other papers. Borrowing the idea of i10-index, this study uses this Google Scholar index for analyzing peoples' activities in Facebook groups. The study uses the i-10-index for the identification of active and influential members in networks. It considers a person to have i-10-index of N if she has at most N posts that received at least 10 likes and/or comments.

Although quantitative SNA is a valuable method for exploring big social network data, there are some limitations with using this method. Effective stakeholder analysis requires an interactive process, e.g., by interviewing or surveying the stakeholders, rather than relying exclusively on archival research (Jepsen & Eskerod, 2009). Big data analysis methods still need to incorporate social science theories and methods in order to integrate contextual factors and detailed behavioral information in the analysis process (Gonza, 2013). Although network analysis helps with exploring big and complex network data, other methods of analysis may be required for deeper exploration of this data. In addition, identifying active volunteers in social networks and exploring their roles as volunteers in disaster recovery, requires exploring their online and on-the-ground activity. Most of the recent studies on the role of online participants in disaster response and management processes focus mainly on evaluating peoples' efforts in the online environment and not their on-the-ground efforts (See Hughes et al., 2014; Hughes and Palen, 2009; Palen, Hiltz, and Liu, 2007; Palen and Liu, 2007; Palen, Vieweg, and Anderson, 2010; Palen et al., 2007; Palen and Vieweg, 2008; Palen et al., 2010b; Starbird et al., 2010; Starbird and Palen, 2013; Starbird, 2010; Starbird, 2011). Exploring the effect of online network members in disaster recovery requires exploring their roles and interactions, both within and beyond the online environment.

IV. CASE STUDIES

This study focuses on Facebook groups that were created during or after Hurricane Sandy for disaster recovery purposes. Hurricane Sandy affected millions of people and required massive recovery and

emergency management efforts (Hughes et al., 2014). Thousands of people joined these Facebook groups to learn about disaster recovery news, offer or ask for help, connect with each other, and pursue other related activities. In addition, several organizations such as, the Humanitarian Free and Open Source Software (FOSS) Project, Information Systems for Crisis Response and Management (ISCRAM), and several local police and fire departments use Facebook as a communication medium for their disaster management efforts. A recent study shows that, among the police and fire departments that used online media during and after Hurricane Sandy, Facebook has been their most popular medium (Hughes et al., 2014).

This study uses Facebook groups as case studies due to their popularity among citizens and local government organizations, and their ability in providing various methods of online participation. Facebook has been the most active social media site in hosting citizen-led groups created for Hurricane Sandy recovery purposes. In addition, Facebook groups provide opportunities for different methods of online expression and activities, including creating, liking, or commenting on posts. Facebook allows researchers to identify the most active and influential members by considering their different types of online engagement.

The study uses Facebook's search engine to find the Facebook groups that were created during or after Hurricane Sandy for disaster recovery purposes. A total of sixty-five open groups were found on Facebook by employing Facebook built-in search using two terms, "sandy" and "hurricane." Fifty-two of the sixty-five groups accepted the researchers' "join" request. The study focuses only on open groups because a variety of graph data is available for the open groups through Facebook APIs. In these groups, all Facebook users can see the group, group members, and what each group member posts. Still, one must join the group to post on the group's wall.

The selected groups are all from the regions affected by the hurricane, but vary in terms of number of participants. The number ranges from 202 to 3,735 participants. The average number of group members is 709. The total number of members in all the groups is more than 38,000.

A. *Methods*

The study employs network analysis methods for identifying the active and influential members in each Facebook group. It also reflects a web-based survey of the members who were identified through network analysis for further exploration.

1. *Network analysis*

In evaluating the effectiveness of the members in each group, several factors come into play: the number of posts that each member has made, the number of likes and comments that each member has received, and the way each post has been treated by receiving likes or comments from different group members. The study uses the i5-index and the Hyperlink-Induced Topic Search **(**HITS) algorithm for finding the active members. The i5-index is a similar indexing method to the i10-index. A person is said to have an i5-index of N if she has at most N posts that received at least five likes and/or comments. HITS is a link algorithm that ranks nodes based on their hub and authority score. For each node the authority score is calculated based on the number of edges that are pointed to it, and the hub score is calculated based on the number of edges that each node points to other nodes (Kleinberg & Kumar, 1999). To calculate the i5-index and HITS scores, a Facebook application using Facebook's Graph API is implemented and all posts in the groups with their likes and comments are retrieved.

The study combines the results of the i5-index with the HITS algorithm analysis (See Kleinberg, 1999) to find the active and influential members in groups. Using this algorithm, a network is built for each group. In this network, nodes indicate members of groups and **links** indicate interactions between members. If a user comments or likes another user's post, a directed link is created from the person who likes or writes a comment to the person who posted on the group's page. The links are also weighted. The weight of each link depends on the number of times corresponding nodes interact with each other. In this algorithm, every node is given an "authority score" and a "hub score." A higher authority score occurs if pages with high hub weights point to the page. A higher hub score occurs if the page points to many pages with high authority weights. In the context of a social network group's interaction, a node is called a good hub if it has links to many other nodes. Also, a node is a good authority if many other nodes link it. To find influential authorities using the HITS algorithm, authority scores are calculated for nodes and these values are normalized on all authority scores.[1]

[1] The values are normalized by dividing each value of the variable by the square root of the sum of squares of all the original values.

2. *Survey*

To learn about the backgrounds, experiences, and activities of the selected participants regarding Hurricane Sandy recovery, web-based surveys were sent to the influential members identified through network analysis using the members' Facebook accounts. All selected members were provided the survey link and asked to participate in the survey.

a. *Network Analysis Results*:

Considering all 52 Facebook groups with the total population of more than 38,000 members, only seven percent of the members have created at least one post on the group wall. Thus, the overwhelming majority of members (ninety-three percent) are silent in their groups. These people are either using the group mainly as a news channel, or not checking the group wall regularly.

After considering different indexes including the H-index, i10-index, and i5-index, the i5-index of greater or equal to five was selected because it covered a broader range of the most active members in the selected groups. Based on this analysis, 168 members from thirty-six groups were selected. In sixteen groups, there was no active group member who met the mentioned indexes; therefore, these groups were omitted from the study for further exploration. In addition, using the HITS algorithm, the nodes (members) with normalized authority scores higher than 0.03 were selected. Overlaying the findings of the i5-index with the HITS algorithm identified 102 individuals as active and influential members in the selected groups. The web survey was sent to all of these members.

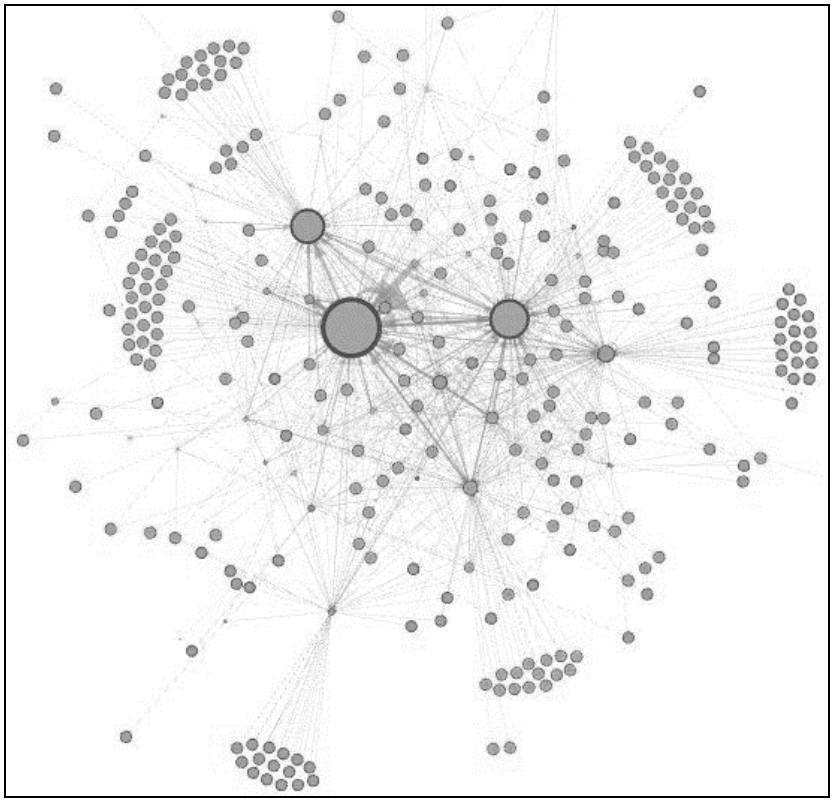

Fig. 1. Network Visualization of One of the Selected Facebook Groups

(The large nodes represent the most active and influential members of the group. Larger nodes are more active in the group. Each cluster represents a sub-community in the network, created based on online interactions among members.)

b. *Survey results*

Out of 102 selected members, 32 participated in the survey, a 31.3 percent response rate; the participants were from 20 different Facebook groups. In the following pages, the survey findings are summarized in three categories: the respondents' backgrounds, their online and on-the-ground activities regarding Hurricane Sandy recovery, and their willingness to contribute to the recovery process.

i. *Respondents' Background*

About 40percent of the online active members in each group are administrators of their groups. Also, about 40 percent of the members learned about the group through Facebook invitations. The level of education among the active group members is relatively high. For example, around 65 percent of them hold bachelors' degrees or higher, and all of them have completed high school.

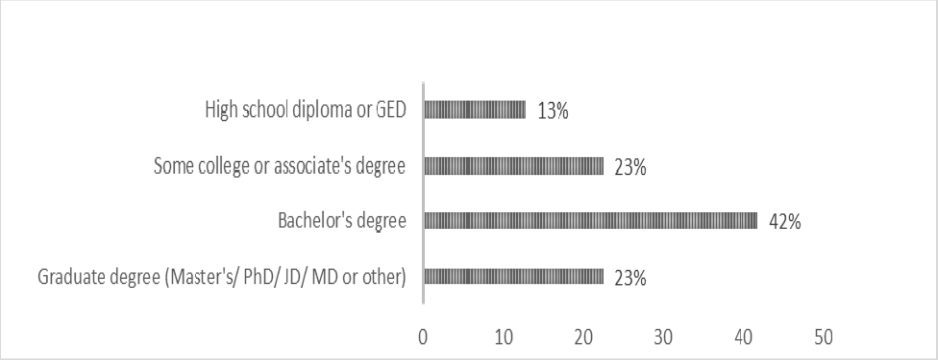

Fig. 2. Educational Background of the Active Members

Moreover, about 31 percent of the participants have had jobs or practical experiences related to management and 33 percent related to professional fields. About 19 percent of them have experience in technical or practical fields.

In addition, all of the respondents except one have been residing in an area that had been highly or very highly affected by the Hurricane Sandy at the time that the disaster happened.

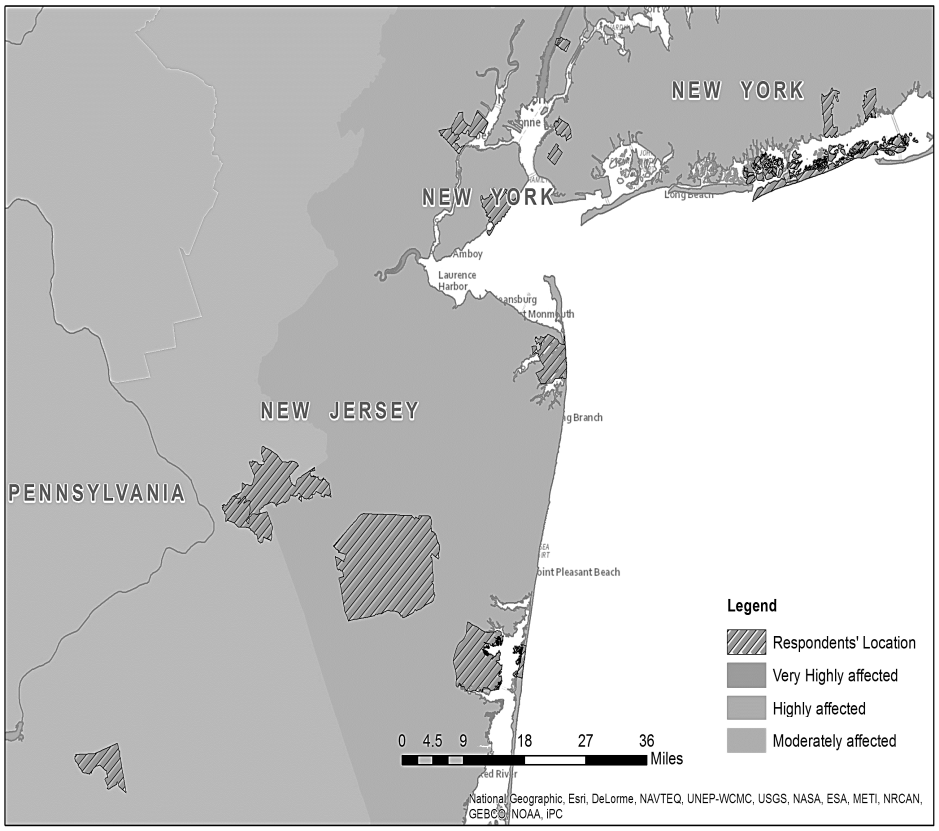

Fig.3. Respondents' Location of Residence at the Time that the Hurricane Happened

Moreover, all of the participants have had the experience of volunteering on the ground for at least eight hours during the last three years. Most of the respondents (77%) have mentioned that they had had the experience of volunteering in a social or community service activity.

ii. *Respondents' online and on the ground activities regarding Hurricane Sandy recovery*

More than half (55%) of the active group members have participated in their groups only for Hurricane Sandy recovery and helping with the affected communities. They have used the forum for several reasons, including informing group members about possible resources or other general recovery-related news, reading about disaster recovery news, organizing events or gatherings, facilitating

communication between group members and a governmental or non-governmental organization, and other related activities.

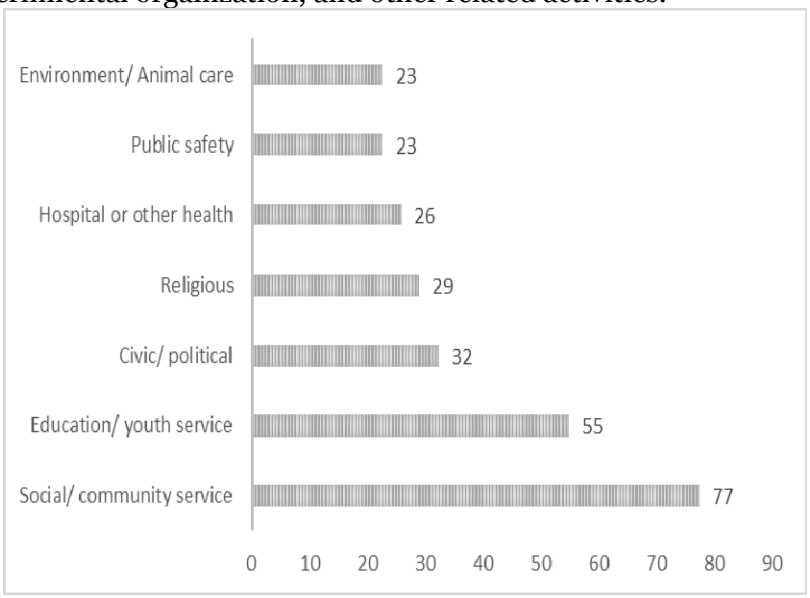

Fig.4. Percentage of the Respondents Who Have Experience in Each Volunteer Activity Category

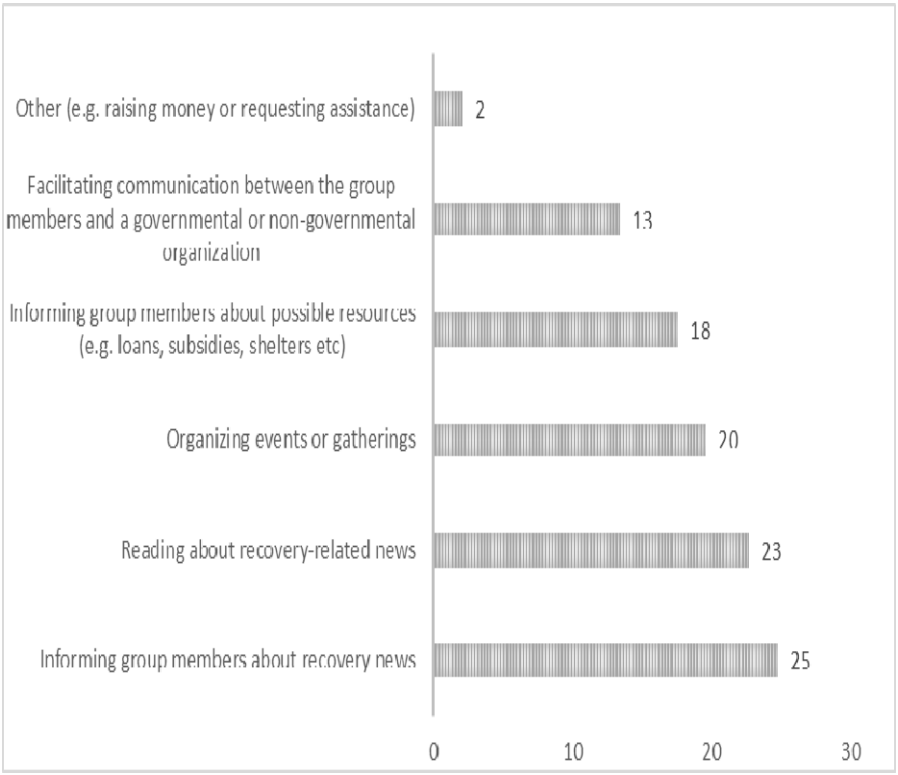

Fig.5. Percentage of different recovery-related activities in the groups

In addition, more than half (61%) of the respondents have mentioned that they have had interactions with a local government or another organization regarding the Hurricane Sandy recovery. The interactions were designed to gain information from those organizations (36%), report citizens' issues to those organizations (33%), facilitate dialogue or interaction between citizens and organizations (26%), or pursue other issues including helping animals or raising money (5%). A little less than half of the respondents (45%) believe that their interactions with local government or other organizations have been influential, or have led to a change or refinement in the recovery process.

Furthermore, the online members have not been active only in the online environment. More than sixty percent (61.3%) of the respondents have been active in on-the-ground activities related to Hurricane Sandy recovery. Among the rest of the members who mentioned that they were not involved in on-the-ground recovery

activities, people mentioned several reasons, including being homeless or having child-raising responsibility. Here are some examples:

"I believe that I would have been more involved on a volunteer basis … [if] the timing been a bit different. As it was, I was homeless for a time and finally relocated in late November…"

"I was a victim of Sandy and unable to volunteer as I was had my home to repair."

"Being the parent of two young children prevents me from being able to do a lot of on-the-ground activity at this time."

iii. *Respondents' willingness for further help as a liaison:*

The survey asked for the respondents' willingness to volunteer five hours a week to help online or on-the-ground as a liaison assisting Hurricane Sandy recovery. The majority of the respondents in both cases mentioned that they were interested in collaborating in the recovery process as a liaison. However, they were more willing to collaborate online (67.7%) compared to work on the ground (55%). The survey also asked for the respondents' willingness to work as a liaison between the local government and citizens for Hurricane Sandy recovery if they were offered a paid job. About half of the respondents (48.4%) answered they might be interested, about one third of them (32.3%) mentioned that they are interested, and about one fifth (19.4%) of them mentioned that they are not interested in doing this.

V. CONCLUSION

Social media is tightly connected to the off-line environment when used for disaster management and recovery efforts. It not only facilitates the integration of the offline and online environments, but also fosters on-the-ground activities. Disaster management organizations should be equipped with skills and technologies to employ social media as a city infrastructure in their recovery processes. Analysis of social network data requires the integration of social science methods with big data analysis methods for learning about contextual factors that affect disaster recovery processes.

A. *Integration of online and on-the-ground activities*

Very few members of the social media groups that were created for Hurricane Sandy response and recovery were actively involved in the recovery process as volunteers. However, these few members effectively bridged the gap between the online and on-the-ground activities. The majority of these people were working with disaster-related organizations, including local governments, to facilitate the interaction between social media users and those organizations. The rest of the active online users who were not active on the ground were involved in facilitating social interactions and information sharing in the online environment. The active online volunteers worked together to integrate and connect the online citizen-led groups (Facebook disaster groups) with more formal organizations. The majority of the active and influential members in social media groups have valuable skills and experiences, and the desire to help with recovery processes as volunteers or professional liaisons. Although most of the members (93%) in these groups were not participating in the online environment, they still have had the opportunity to hear from those active members who are in direct contact with on-the-ground organizations to learn about disaster recovery news or opportunities.

This study does not argue whether social media use increases on-the-ground activities; instead, it concludes that social media facilitates collaboration and integration of on-the-ground and online volunteer activities for disaster management efforts. Social media also provides opportunities for people to participate in recovery processes as volunteers, regardless of their desire or ability for being involved in on-the-ground activities.

B. *Organizational considerations:*

Citizens are increasingly using social media as a city infrastructure in different stages of disaster management. Their interactions in social media generate a new social infrastructure (see Hughes et al., 2014) which is constantly evolving and regenerating itself (see Zittrain, 2006). Social interactions may change in these networks. As we saw in this study, about half of the active Sandy group members started interacting with other group members for non-disaster related issues. Local governments and disaster management organizations should support the creation and life of these dynamic social structures. Organizations should consider using social media as a tool for facilitating disaster recovery efforts. They should allocate personnel resources for facilitating discussions and communications in these

networks and identifying potential group members who can help with recovery processes as volunteers or professional liaisons. The analysis of data generated through social media helps understand the structure of the online communities which can connect to on-the-ground activities. Although statistical social network analysis is valuable in analyzing big data generated through social media groups and understanding their relationships and hierarchies, it provides an insufficient basis for fully analyzing their complexity. Incorporating other methods, including surveys, interviews, and content or sentiment analysis is helpful for a deeper exploration and interpretation of network dynamics. The organizations that are involved in disaster recovery should either gain the required skills for analyzing this complexity, or foster their collaboration with outside organizations to help them with this process. "Politics in Facebook goes to where people are, not where we would like them to be." (Chadwick, 2008, 30). Disaster recovery organizations should consider actively searching big network data for identifying potential volunteers and stakeholders, instead of focusing on passive methods of volunteer recruitment. With the fast growth of location-based online networks (e.g. Facebook, Nextdoor, Uber) big and little data both provide valuable opportunities for disaster management organizations to identify and recruit potential stakeholders to help with different stages of recovery processes. Interpretation of big data requires understanding the contextual factors, through the incorporation of social science methods into big data analysis. Future research is required to evaluate the capacity of disaster management organizations not only in analyzing and facilitating interactions in social media groups, but also incorporating these groups in their disaster management processes.

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